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(71) Applicant
General Electric Company,
1 River Road,
Schenectady 12305,
State of New York,
United States of America
(72) Inventors
Max Willard Stanely,
Richard David Pratt
(74) Agent
Brookes and Martin,
High Holborn House,
52—54 High Holborn,
London,
WC1V 6SE

(54) Fibrous bearing material

(57) A laminated composite bearing material has a bearing portion ply comprising fabric of, for example, glass fibers and interwoven fluorocarbon resin fibers. The fabric is woven in a manner such that the surface to be used as the bearing surface of the resultant molded article has predominantly or substantially PTFE fibers exposed. Additionally, an opposing surface is woven so as to have the other fibers exposed thereon to facilitate bonding to a support body ply. The body ply preferably comprises at least one layer of glass fiber fabric, and is predeterminedly oriented relative to the bearing portion ply or plies for improved strength in the laminated structure. Finally, impregnating the body and the bearing portions, to bond them together, is an adhesive matrix.

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Fig. 1

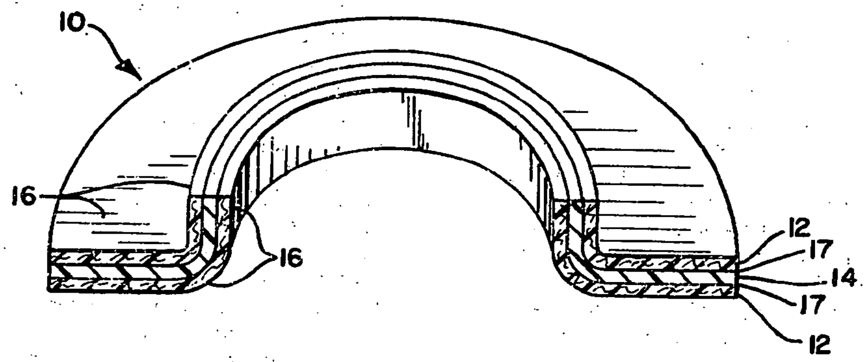


Fig. 2

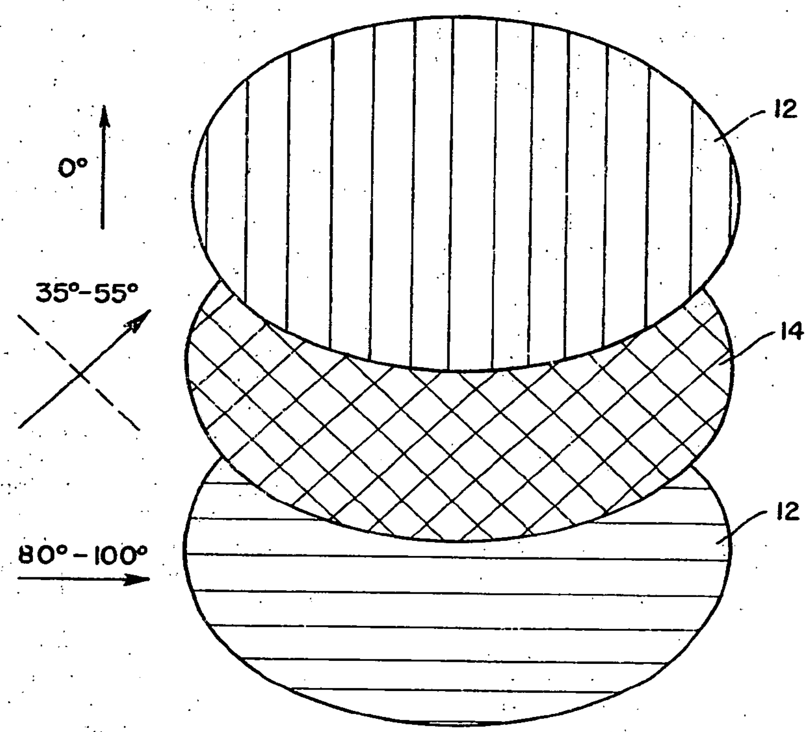
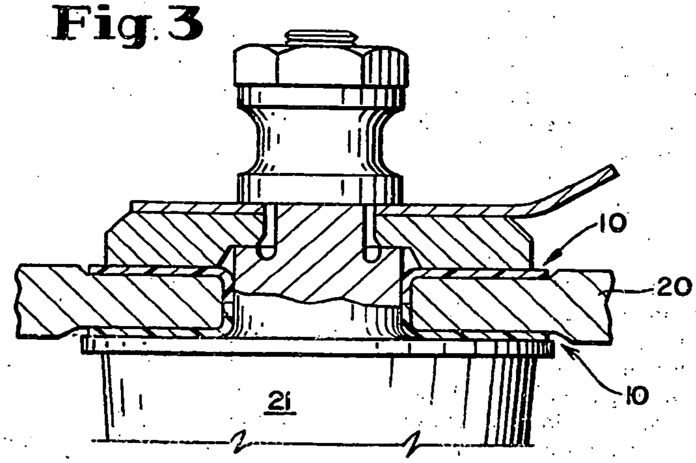


Fig. 3



SPECIFICATION

A composite article with improved bearing portion

According to the present invention, there is provided an improved composite article having a bearing laminate comprising a fabric of glass fibers and interwoven fluorocarbon resin fibers. Preferably, the fabric is woven in a manner such that the surface to be used as the bearing surface of the resultant molded article is constituted predominantly or substantially of exposed PTFE fibers. Additionally, an opposing surface is woven so as to have glass fibers exposed thereon to facilitate bonding to a support body laminate. A specific embodiment in the form of a bushing comprises two annular bearing laminates disposed on opposing sides of an annular body laminate and constituting a multi-ply article. The body ply comprises at least one layer of glass fiber fabric, and is predeterminedly oriented relative to the bearing plies for improved strength in the laminated structure. Finally, impregnating the body and the bearing laminations, to bond them together, is an adhesive matrix. Examples of preferred adhesives for forming the matrix are polymer resins capable of withstanding high temperatures including expoxies and polyimides.

Figure 1 is a perspective sectional view of one embodiment of the composite article of the present invention in the form of a bushing.

Figure 2 is an exploded sketch illustrating the relative angular orientations of the glass fibers of the article.

Figure 3 is an enlarged fragmentary sectional view of a pair of cooperating bushings in a bearing assembly.

Referring to Figure 1, the article shown generally at 10 in the form of a molded laminate bushing can be used, for example, in a variable stator assembly in the compressor of a gas turbine engine. The bushing is a composite structure comprising a cured resin matrix of epoxies or polyimides containing and bonding together body and bearing laminations therein. Such a configuration can be obtained by pressing and molding the article in an appropriately shaped die by methods well known in the art. The bushing comprises a pair of outer bearing portions or laminations 12 and an intermediate body or lamination 14. The body 14 is a glass fiber element such as a glass fiber clot. The two outer bearing portions or laminations 12 each include two surfaces: an outer surface 16 and an inner surface, indicated generally as 17. Each lamination 12 comprises a compound woven fabric of bondable fiber material such as glass fibers and interwoven low friction fiber material such as PTFE fibers. This compound fabric is so woven as to have substantially the low friction fibers exposed at the outer surface 16 to minimize friction between such surface and a mating component during the wearing life of outer layer 12. The low friction fiber material, in most cases, does not bond readily with the material of the body 14, and in order to assure a good bond, the bondable fibers are woven on the rev rse or inner sid of the woven low friction fibers so that on the inner surface 17 a readily bondable surface will be provided.

It is to be understood that various types of weaves can be employed for forming the compound fabric having on one side thereof the low friction fibers and on the opposite side thereof the bondable fibers. One example is found in U.S. Reissue Patent 24,765—C. S. White. Another example known to those skilled in the art and used in the illustrated embodiment of the present invention is a "compound satin weave" of bondable fibers of glass interwoven with low friction fibers of PTFE. This compound fabric is woven such that the surface to be used as the outer bearing surface 16 of the resultant molded laminate bearing has substantially PTFE fibers exposed. The opposing inner surface 17 is so woven as to contain glass fibers running only in the fill or weft, direction and PTFE fibers running in the warp and weft directions.

Fibers other than glass fibers may be utilized in the bearing and body laminates as long as the fibers of the bearing laminate for interweaving with the low friction fluorocarbon resin fibers are readily bondable to the fibers of the body. Glass fiber is specifically used in both the bearing and body laminates of the embodiment disclosed because in addition to its bondable characteristic, it also possesses relatively high material strength. Utilization of glass fiber fabric in the body of the bearing article results in a finished article possessing substantial deformation resistance. Utilization of glass fibers interwoven with the low friction fluorocarbon resin fibers of the bearing laminate results in a structurally reinforced bearing laminate being readily bondable to the body. Additionally, the bondable fibers of the bearing laminate can be predeterminedly oriented relative to the fibers of the body to provide a resultant bearing article having directionally preferred strength characteristics. For example, all of the fibers of the body and the bondable fibers of the bearing laminates can be aligned parallel to a bearing article longitudinal axis thus providing an article having a relatively high strength characteristic in the longitudinal axis and a correspondingly relatively low strength characteristic in the transverse plane. Alternatively, the bondable fibers of the bearing laminate can be biased relative to the fibers of the body for tailoring the directional strength characteristic of the bearing article to match a particular direction of applied bearing loading. It will be understood from the foregoing that one can obtain a bearing article having quasi-isotropic material strength by providing bearing plies wherein the fibers are uniformly distributed and equally angularly spaced r lative to each other. For example, if one were to view a planar projection normal to a plane of the bearing article showing the relative orientation of the bondable fibers of the bearing

ply or plies with respect to the bondable fibers of the body ply or plies, one would s e a relatively angular orientation of fibers as shown in Figure 2.

More specifically, Figure 2 illustrates the relative angular orientation of the glass fibers of the bearing laminate fabric with respect to the glass fibers of the body laminate 14 in a quasi-isotropic embodiment of the invention. The body ply 14 comprising at least one layer of glass fiber fabric, has at least the weft or warp fibers oriented at an angle in the range of approximately 35° to approximately 55° relative to the glass fibers in the bearing plies 12. In addition, the glass fibers in the fill direction of the two bearing plies 12 are relatively oriented at an angle in the range of approximately 80° to approximately 100°. This arrangement of glass fibers results in a quasi-isotropic composite article having the strength necessary to sustain loads imposed in both the wearing and fatigue modes of the severe gas engine compressor environment. Additionally, this composite structure results in a finished manufactured article which is dimensionally stable and not subject to deformation following the manufacturing process.

Application of the bushing of Figure 1 is shown in more detail in Figure 3 illustrating a pair of upper and lower cooperating bushings 10 as used in a variable stator assembly in the compressor of a gas turbine engine. The upper and lower bushings are disposed about member 20 such as a compressor casing. Each bushing has two bearing surfaces available for cooperation with opposed cooperating bearing surfaces. For example, the lower bushing is additionally disposed between compressor casing 20 and engine member 21, such as a compressor vane, and has both bearing surfaces in cooperation therewith.

One manner of manufacturing the bushing of Figure 1 involves the preparation of a body layer of woven glass and a pair of bearing layers of glass-PTFE fabric. The body lamination comprises a "crowfoot 120" fabric of glass fibers and each of the bearing laminations comprises a "compound satin weave" of glass and PTFE fibers. These weaving arrangements are well known to those skilled in the art and will, therefore, not be further described in detail.

Blanks of the body and bearing laminations are first impregnated at room temperature with polymer resin. The resin selected particularly for high temperature operation is a polyimide type thermosetting resin with limited evolution of volatile by-products during preforming or curing. Such types are commercially available from several sources such as Monsanto Company and E.I. duPont de Nemours & Company.

After impregnation, each blank is partially cured in an air circulating oven, for example, at 225°F. for 30 minutes, primarily to drive off most of the solvents. In the art, this is known as B staging. The blanks are then cut to size for matched die molding in a die mold and additionally staged for 2 to 4 hours at 225°F. The partially cured cut laminations are th n stacked in the die mold in the sandwich arrangement shown in Figure 1, with the glass fabric body forming the centermost lamination for higher strength purposes and the glass-PTFE fabric laminations forming the outermost portions. In a preferred embodiment the individual plies are predeterminedly oriented as shown in Figure 2 for providing improved strength in the composite laminated structure. Before the die mold is closed the partially cured stacked laminations are allowed to soften in the die mold for 45 to 60 seconds at a temperature of 350°F. The die mold is then closed and maintained at 350°F. while applying a pressure of 5000 psi to the stacked laminations. This curing stage is held for 8 to 10 minutes. The stacked laminations then undergo a post-cure process which includes maintaining the temperature at 350°F. for 30 minutes followed sequentially by raising the temperature in steps of 50°F. up to and including 600°F. and maintaining each of these temperatures for 30 minutes, with the last temperature of 600°F. being maintained for 480 minutes. Finally, the article thus cured is allowed to cool to room temperature and finished to final shape by removing excess material and burrs, if any. It should be understood by those skilled in the art that the temperatures and holding periods specified above are all approximate values and that they may be varied and still result in an adequate finished article.

Due to the fact that the PTFE fibers are in the bearing lamination of the article, the bearing lamination and its bearing surface are provided with improved long-lasting characteristics of low coefficient of friction attributed to the PTFE material. In addition, because the PTFE fibers are interwoven with glass fibers, they are firmly incorporated in the resultant fabric.

Furthermore, by bonding the glass-PTFE bearing lamination fabric to a fiber glass body in a matrix of a polymer resin, a dimensionally stable composite article is produced which is effected for resisting deformation and retaining its shape during manufacture as well as under the extreme temperature and loading conditions encountered during use.

Claims

1. A composite bearing article comprising:

a body laminate comprising bondable fibers;

a bearing laminate comprising a fabric of bondable fibers and interwoven low friction fluorocarbon resin fibers;

said bearing laminate having an inner surface bonded to and disposed on at least one side of said body laminate and an outer surface constituting a low friction bearing surface; and

said body and bearing laminates being impregnated with and bonded together by a cured resin.

2. The composite bearing article of claim 1, wherein said cured resin is selected from the

group consisting of epoxies and polyimides.

3. The composite bearing article of claim 1, wherein said bondable fibers of both said body and bearing laminates are glass fibers.

4. The composite bearing article of claim 3, wherein:

said glass fibers in said bearing laminate run substantially in the weft direction and said fluorocarbon resin fibers run in the warp and weft directions;

said bearing laminate inner surface being bonded to said body laminate at said glass fibers; and

said bearing laminate outer surface being constituted substantially of fluorocarbon resin fibers.

5. A composite bearing article according to claim 1, wherein a bearing laminate of the therein defined type is provided on each of opposite sides of said body laminate.

6. A composite annular spacer article for use between opposed cooperating bearing surfaces comprising:

an annular body laminate comprising bondable fibers;

a pair of annular bearing laminates each comprising a fabric of bondable fibers and interwoven low friction fluorocarbon resin fibers;

each bearing laminate having an inner surface bonded to a side of said body and an outer surface constituting a low friction bearing surface; and

said body and bearing laminates being impregnated with and bonded together by a cured resin selected from the group consisting of epoxies and polyimides.

7. The article of claim 5 or 6, wherein:

the inner surface of each bearing laminate comprises exposed bondable fibers bonded to said body laminate; and

the outer surface of each bearing laminate is constituted substantially of exposed low friction fluorocarbon resin fibers.

8. The article of claim 5 or 6, wherein the bondable fibers in each bearing laminate are predeterminedly oriented with respect to the bondable fibers of the body laminate for providing directionally preferred strength characteristics in said article.

9. The article of claim 5 or 6, wherein:

the inner surface of each bearing laminate comprises exposed bondable fibers bonded to said body laminate;

the outer surface of each bearing laminate is constituted substantially of exposed low friction fluorocarbon resin fibers; and

the bondable fibers in each bearing laminate are predeterminedly oriented with respect to the bondable fibers in said body laminate for providing directionally preferred strength characteristics in said article.

10. The article of claim 9, wherein said body laminate comprises a woven fabric wherein the bondable fibers run in both weft and warp directions.

11. The article of claim 9, wherein said fluorocarbon resin fibers are PTFE.

12. The article of claim 9, wherein said bondable fibers of both said body and bearing laminates are glass fibers.

13. A composite annular spacer article for use between opposed cooperating bearing surfaces, comprising:

an annular body laminate of woven glass fiber fabric including glass fibers running in weft and warp directions;

a pair of annular bearing laminates each comprising: a fabric of glass fibers running substantially in the weft direction and interwoven low friction PTFE fibers running in the warp and weft directions; an inner surface comprising exposed glass fibers bonded to a side of said body laminate; and an outer surface constituted substantially of PTFE fibers; and

wherein at least the weft or warp glass fibers of said body laminate are oriented at an angle in the range of approximately 35° to approximately 55° relative to the glass fibers of the inner surface of each said bearing laminates, said glass fibers of the inner surfaces of said bearing laminates are relatively oriented at an angle in the range of approximately 80° to approximately 100°, and the body and the bearing laminates are impregnated with and bonded together by a cured resin selected from the group consisting of epoxies and polyimides.

14. A composite bearing article substantially as hereinbefore described with reference to and as illustrated in the drawings.

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